ANNUAL VARIATION OF AITKEN NUCLEI CONCENTRATION AT WASHINGTON, D.C.

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ABSTRACT

A continuous 15-mo. morning and afternoon Aitken nuclei concentration measurement was made during 1964–1965 at Washington, D.C. The climatological means and extreme values of the Aitken nuclei concentration were obtained and are presented in graphical form. A mean monthly stability index to measure the local stability of the atmosphere is developed and compared to the mean monthly values of the Aitken nuclei concentration.

1. INTRODUCTION

During 1964 and 1965 an environmental study of atmospheric aerosols was conducted on the U.S. Naval Observatory grounds, in northwestern Washington, D.C. Among the data collected during this study is a continuous 15-mo. Aitken nuclei concentration count.

The laboratory has four Pollak photo-electric condensation nucleus counter systems, model 1957, with convergent light-beam. Two of these have been calibrated against Dr. Pollak's standard photo-electric counter in Dublin, Ireland. One of the remaining two has been compared to the two calibrated counters and was used to determine the Aitken nuclei concentration.

2. RESULTS

Figure 1 shows the result of the Aitken nuclei concentration study. Morning and afternoon counts were made daily, Monday through Friday for 15 mo., October 1964 through December 1965. Each morning and afternoon count is the average of at least five Aitken nuclei concentration measurements. The morning counts were made at about 0800 EST, the afternoon counts at about 1600 EST. During that portion of the year when Daylight Saving Time was in effect, the counts were made at about 0800 and 1600 EDT. Morning counts were thus made during the second hour after sunrise throughout the year. Since human activity was regulated by the same time cycles, the Aitken nuclei concentration counts were made at the same time daily with respect to those human activities which generate Aitken nuclei.

The data present four kinds of information that were derived from the Aitken nuclei concentration counts: the weekly morning average count; the maximum daily morning count occurring during that week; the weekly afternoon average count; and the minimum daily afternoon count occurring during that week.

The high weekly averages and high daily counts were normally associated with stagnating high pressure systems, especially during such periods in the autumn known as "Indian Summer." The low weekly averages and low daily readings were associated with surface maritime air that had a short traverse across the continent from the southeast, the Atlantic Ocean being the source region.

The lowest minimum daily count recorded at the laboratory during 1964 was in September, within air circulating over Washington, D.C., from Hurricane Gladys. The afternoon count was 13800 nuclei ml.$^{-1}$ and the following morning the count was even lower at 12800 ml.$^{-1}$ The Atlantic Ocean usually has an Aitken nuclei concentration of from several hundred to about one thousand nuclei ml.$^{-1}$ [1]. However, since the Atlantic Ocean is approximately 150 km. to the east, the increase of Aitken nuclei concentration is attributed to the influence of the continental processes of Aitken nuclei production. These points are not plotted on figure 1, since they did not occur within the 15-mo. continuous record, and are reported only as a supplement to the study.

From observations of the weather conditions during the data acquisition period, it appears that atmospheric stability has some function in determining the average Aitken nuclei concentration at the surface of the earth. Counts were generally higher in the morning when the aerosol had collected below the inversion layer than in the afternoon when thermal convective activity had mixed

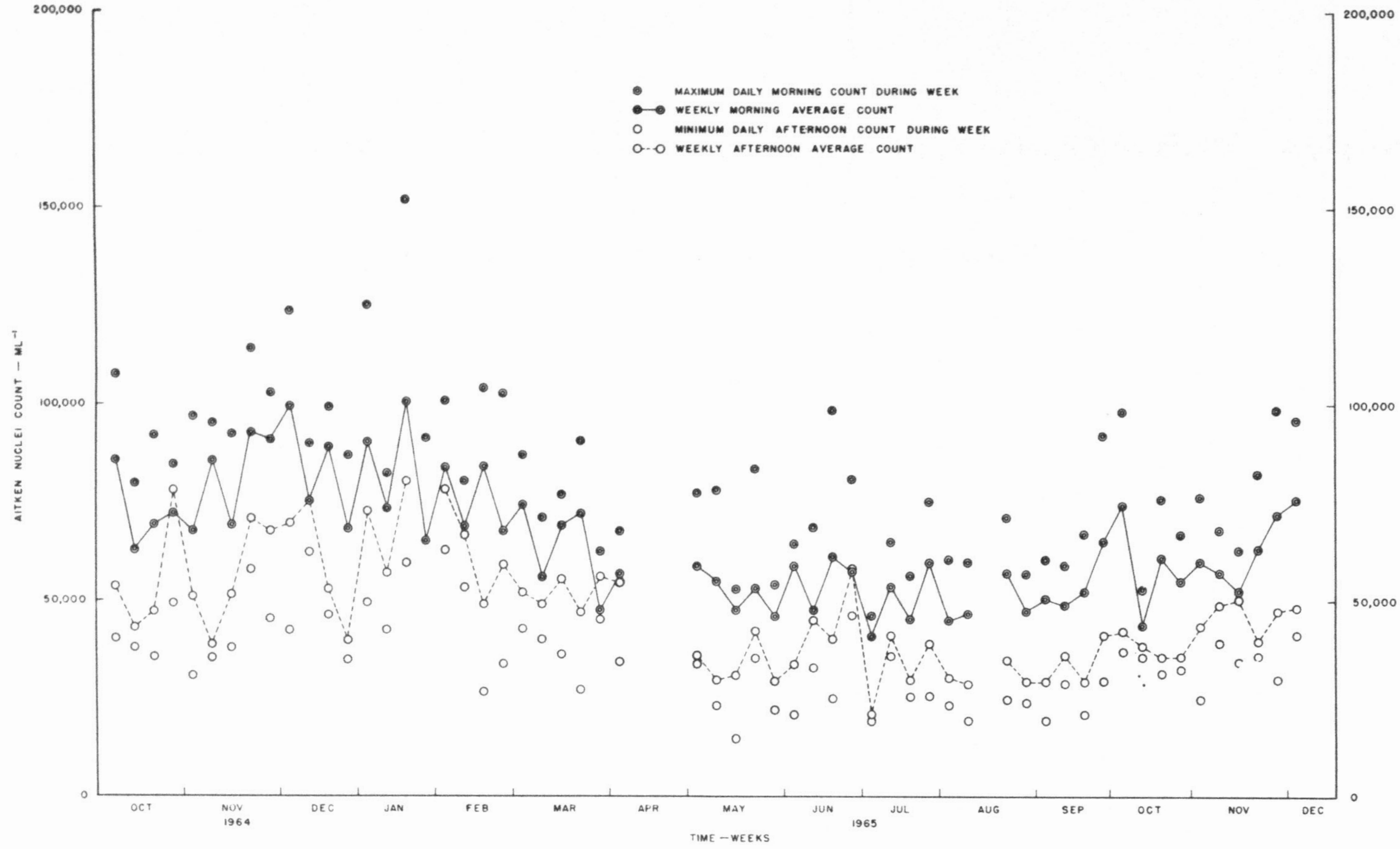

FIGURE 1.—Weekly values of the Aitken nuclei concentration from October 1964 through December 1965.

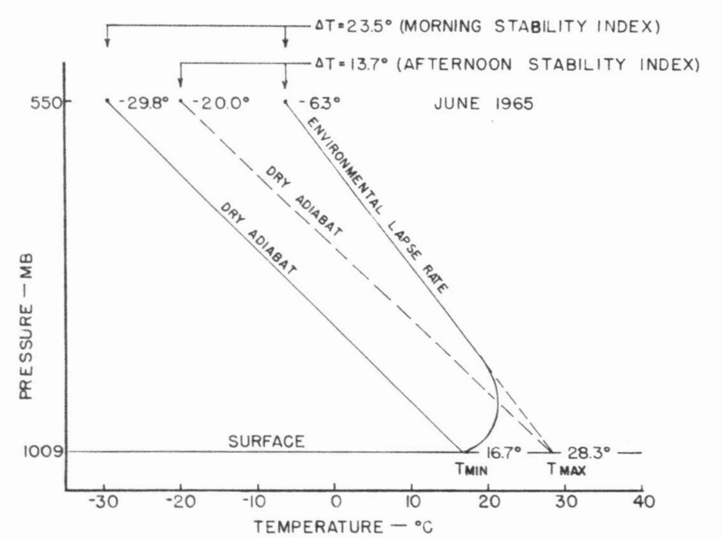

FIGURE 2.—Adiabatic diagram for the calculation of the stability index for June 1965.

the lower air layers with clean air from aloft. Similar observations have been reported previously by Landsberg [1].

A stability index was devised to test the hypothesis that the Aitken nuclei concentration at the earth's surface could be correlated with the stability of the atmosphere. The stability index was defined as the difference between the adiabatic lapse rate temperature and the environmental lapse rate temperature at 550 mb., when both lapse rates have a common temperature at the ground. Increasingly larger index corresponds to an increasingly stable atmosphere and increasing Aitken nuclei count by this definition. The 550-mb. level was chosen since at this height the Aitken nuclei concentration is less than one percent of that at the surface, according to Weickmann [5].

Figure 2 is an example of a lapse rate diagram for the calculation of the stability index for June 1965. The monthly average daily minimum temperature (T_{min}) and the monthly average 550-mb. temperature are plotted on an adiabatic diagram. The morning stability index is the difference between the adiabatic lapse rate and the environmental lapse rate at 550 mb., and is 23.5° C. Similarly, the afternoon stability index, using the monthly average daily maximum temperature at 550 mb., arrives at a difference between the adiabatic lapse rate and the environmental lapse rate to 550 mb. of 13.7° C. The monthly average values of T_{min}, T_{max}, and the monthly average temperature at the 550-mb. level were taken

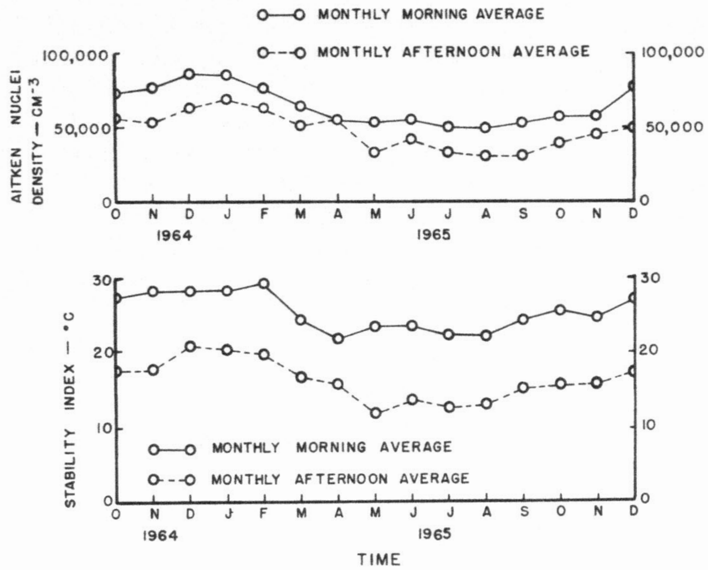

FIGURE 3.—Comparison of monthly stability index values to monthly Aitken nuclei concentration.

from climatological data for Washington, D.C., published by the U.S. Weather Bureau [3].

Figure 3 is a comparison of monthly stability index values to monthly Aitken nuclei concentration counts. The lower graph is a plot of the stability indices by months. The results of figure 2 for June 1965 are plotted as 13.7° C. and 23.5° C. for the afternoon and morning indices respectively. The index values are lower in the summer season than in the winter, lower in the afternoon than in the morning. Note the stability index is lower for October, November, and December of 1965 than it is for October, November, and December of 1964, by respective months.

The February 1965 stability index exhibits a high point in the morning. This was due to an increase in the average temperature at the 550-mb. level, but the minimum surface temperature in the morning did not increase correspondingly as did the afternoon surface temperature. This may be the result of colder earth temperatures held over from winter which affect the morning $T_{\min}$ value.

The upper graph of figure 3 is a plot of the monthly average values of the Aitken nuclei concentration counts. The common value of the April 1965 morning and afternoon values may result from an insufficient amount of data being available for this month. The Aitken nuclei concentration count curves follow the stability index curves in general form. In some cases, month-to-month correlation of the perturbations are observable. The Aitken nuclei count for October, November, and December 1965 is lower respectively than that for October, November, and December 1964, as was the stability index. The correlation coefficient between the monthly morning stability index and the monthly morning average Aitken nuclei concentration for figure 3 is $r=0.92$. Similarly, the correlation coefficient for the afternoon is $r=0.87$.

TABLE 1.—*Comparison of the increase of Aitken nuclei concentration from this study, 1964–65, to those of Wait [4] and Torreson and Wait [2] for 1927–31. Parenthetical values are the number of observations used to determine the Aitken nuclei concentration*

	March	July	October	November
1927–31	28800 (32)	10490 (18)	19200 (29)	26950 (48)
1964–65	58550 (39)	42590 (37)	57420 (64)	59350 (69)
Increase (percent)	203	406	299	220

Also, when the Aitken nuclei concentration is plotted as a function of the stability index the slope of the linear regression curve is greater for the morning data than it is for the afternoon data.

Daily values of the stability index have not been computed for comparison to the daily value of the Aitken nuclei concentration.

When figure 3 is compared to figure 1, it can be seen that the effect of the variation of weather cycling is averaged out, and the average annual variation of the Aitken nuclei concentration is more apparent. Data from Landsberg [1], when plotted in a similar manner, show the same type of annual variation.

Aitken nuclei concentration data were taken between 1927 and 1931 by Wait [4] and Torreson and Wait [2] at the Carnegie Department of Terrestrial Magnetism in Washington, D.C., 2 km. north of the U.S. Naval Observatory. A comparison of their data and the present study is shown in table 1. The data presented from Wait [4] and Torreson and Wait [2] are the averages of all their observational data between 0900 and 1600 EST for the several (4 to 6) days of data presented for each month. The data available are few and covered the years 1928 to 1931. The data from the present study were the average of all observational data, morning and afternoon, available for the given month. Parenthetical values are the total number of observations that have been averaged to arrive at the Aitken nuclei concentrations presented in table 1. The fourfold increase for July since the 1928–1931 period corresponds to the increase of population in the Washington metropolitan area between 1930 and 1964. The Aitken nuclei concentration of the cooler months has not increased proportionately to population. This may be due to the fact that coal which was previously used for home heating has been mostly replaced by oil and natural gas.

Diurnal variation of the nuclei concentation results in curves (not shown) similar to those of Landsberg [1] and Wait [4].

3. CONCLUSION

The study established the climatological means and extreme values of Aitken nuclei concentration to be expected during the daylight hours of a working day in the vicinity of the laboratory at the U.S. Naval Observatory. However, these counts should not be considered as being representative of any other area of Washington, D.C. The U.S. Naval Observatory is located in a predominately residential area of northwest Washington, D.C. Other areas of Washington that contain light industrial factories and the business district would have a greater Aitken nuclei concentration.

Caution must be used in attempting to correlate a stability index directly to a given value of the Aitken nuclei concentration for a given locality. The annual variation of nuclei concentration must depend upon seasonal human activity and natural nuclei production processes as well as stability of the atmosphere. Thus, although the form of the two curves of figure 3 is similar, the correlation of corresponding month's nuclei concentration and stability index for other locations may not be a simple linear function. The correlation coefficients of the present study indicate that there exists a useful linear relationship between the Aitken nuclei concentration and the stability index for the laboratory site in Washington, D.C. However, if coal had continued to be used as heating fuel, a curvilinear correlation coefficient might have been necessary. Also, table 1 indicates that the same linear regression curve would not describe the relationship of Aitken nuclei concentration to stability index in the same locality over a period of approximately 35 years.

The coefficients of correlation of the Aitken nuclei concentration to the stability index are approximately equal for the morning and afternoon measurements. However, the two sets of data are derived from measurements of the nuclei concentration when there was a difference in the rates of natural nuclei production, human activity nuclei production, and loss by turbulent diffusion to upper levels of the atmosphere. The results are two linear regression curves that are not identical, and indicate the necessity of restricting critical comparison of daily nuclei concentration to those measurements which are made at the same hour.

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